

4.2 Surface Water and Sediment Surveillance



G. W. Patton

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the potential impact to the public and aquatic environment from radiological and chemical contaminants that originated at Hanford. Surface-water bodies included in routine surveillance were the Columbia River and associated riverbank springs, onsite ponds, and offsite irrigation sources (Figure 4.2.1). Sediment surveillance was conducted for the Columbia River and riverbank springs. Tables 4.2.1 and 4.2.2 summarize the sampling locations, types, frequencies, and analyses included in surface water and sediment surveillance during 2003. This section describes the surveillance efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-14687, APP. 1.

4.2.1 Columbia River Water

The Columbia River is the second largest river in the continental United States in terms of total flow and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production was based, in part, on the abundant water supply offered by the river. The river flows through the northern edge of the site and forms part of the site's eastern boundary. The river is used as a source of drinking water for onsite facilities and communities located downstream from the Hanford Site. Water from the river immediately downstream of the site also is used for crop irrigation in Benton and Franklin Counties. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including hunting, fishing, boating, water-skiing, and swimming.

Originating in the Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 670,000 square kilometers

(260,000 square miles) en route to the Pacific Ocean. The flow of the river is regulated by three dams in Canada and eleven dams in the United States; four of the dams are downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam and McNary Dam is the nearest downstream dam from the site. The Hanford Reach of the Columbia River extends from Priest Rapids Dam downstream to the head of Lake Wallula (created by McNary Dam) near Richland, Washington. The Hanford Reach is the last stretch of the Columbia River in the United States upstream of Bonneville Dam (first dam upstream from the ocean) that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at Priest Rapids Dam. Changing river flows result in changes in concentrations of contaminants in river water for users downstream of Hanford (PNL-8531). Annual average flow of the Columbia River downstream of Priest Rapids Dam is approximately 3,400 cubic meters (120,000 cubic feet) per second (WA-94-1). In 2003, the Columbia River had below normal flows; the average daily flow rate downstream of Priest Rapids Dam was 2,860 cubic meters (101,000 cubic feet) per second. The peak monthly average flow rate occurred during June (4,160 cubic meters [147,000 cubic feet] per second) (Figure 4.2.2). The lowest monthly average flow rate occurred during September (1,910 cubic meters [67,500 cubic feet] per second). Daily flow rates varied from 1,210 to 5,130 cubic meters (42,600 to 181,000 cubic feet) per second during 2003. As a result of fluctuation in discharges, the depth of the river varies significantly over time. River stage (water surface level) may change along the Hanford Reach by up to 3 meters (10 feet) within a few hours (see Section 3.3.7 in PNL-10698). Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately half the

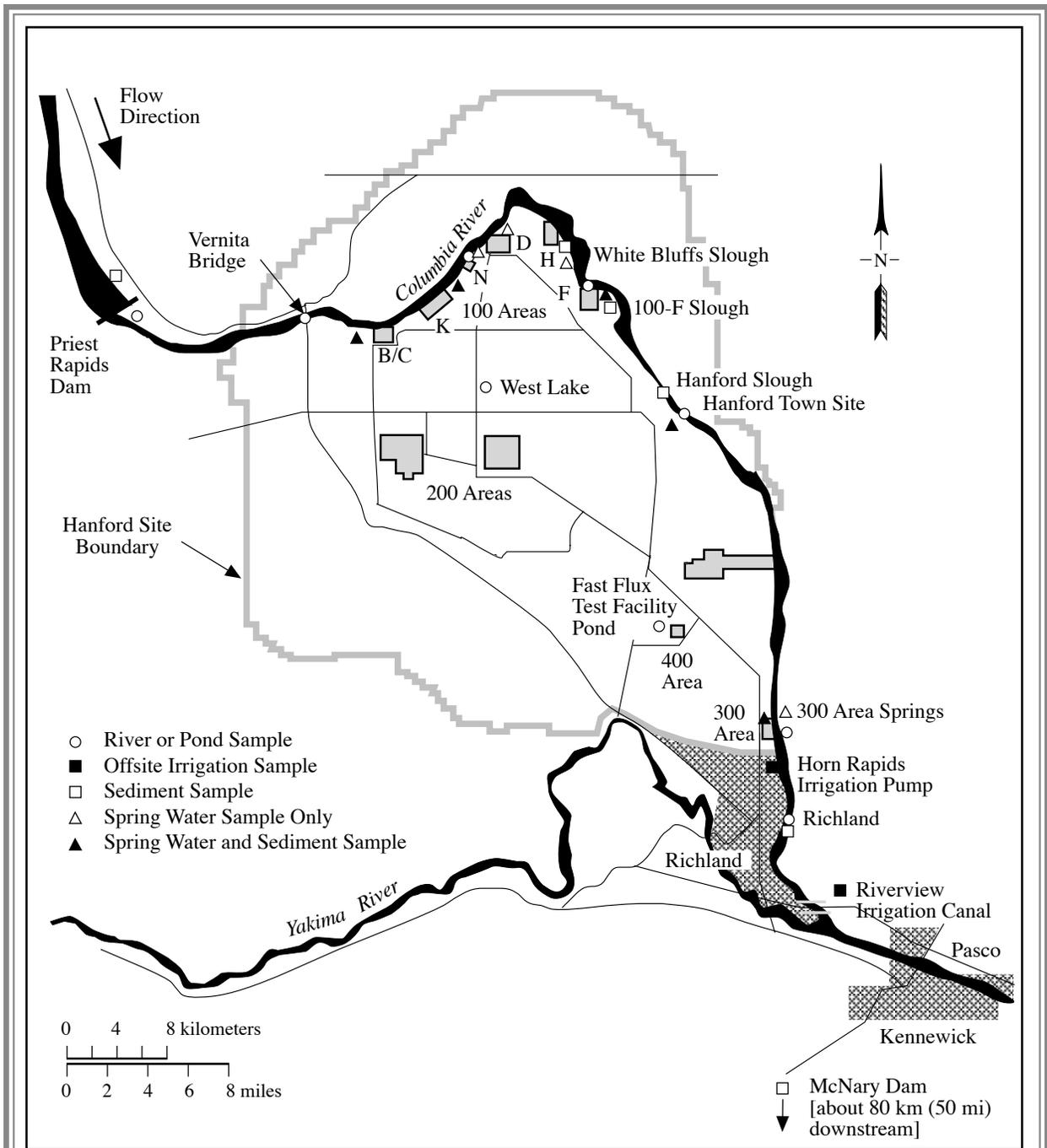


Figure 4.2.1. Hanford Site Environmental Surveillance Project Sampling Locations for Water and Sediment, 2003

Table 4.2.1. Surface Water Surveillance On and Near the Hanford Site, 2003

Location	Sample Type	Frequency ^(a)	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland	Cumulative	M Comp ^(b) Q Comp ^(e)	Alpha, beta, lo ³ H, ^(c) ⁹⁰ Sr, ⁹⁹ Tc, U ^(d) ¹²⁹ I
	Particulate (filter)	M Cont ^(f) Q Cont ^(g)	Gamma energy analysis Pu ^(h)
	Soluble (resin)	M Cont Q Cont	Gamma energy analysis Pu
Vernita Bridge and Richland 100-F, 100-N, 300, and Hanford town site	Grab (transects)	Quarterly	lo ³ H, ⁹⁰ Sr, U
	Grab (transects)	Annually	lo ³ H, ⁹⁰ Sr, U
Columbia River - Chemical			
Vernita Bridge and Richland ⁽ⁱ⁾ 100-F, 100-N, 300, and Hanford town site	Grab	3/year	Temperature, dissolved oxygen, turbidity, pH, alkalinity, anions, suspended solids, dissolved solids, specific conductance, hardness (as CaCO ₃), Ca, P, Cr, Mg, N-Kjeldahl, Fe, NH ₃ , NO ₃ + NO ₂ , metals (filtered and unfiltered), anions
	Grab (transects) Grab (transects)	Quarterly Annually	VOA ^(j)
	Grab (transects)	Annually	Metals (filtered and unfiltered), anions
Onsite Ponds			
West Lake Fast Flux Test Facility pond	Grab	Quarterly	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis
	Grab	Quarterly	Alpha, beta, ³ H, gamma energy analysis
Offsite Irrigation Water			
Riverview irrigation canal Horn Rapids	Grab	3/year	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
Riverbank Springs			
100-H Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, metals (filtered and unfiltered), anions
100-F Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
100-B Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
100-D, 100-K, and 100-N Areas	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, gamma energy analysis, metals (filtered and unfiltered), anions, VOA (100-K Area only)
Hanford town site	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, metals (filtered and unfiltered), anions
300 Area	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions, VOA

(a) M = Monthly; Q = Quarterly; Comp = Composite; Cont = Continuous.

(b) M Comp indicates river water was collected hourly and composited monthly for analysis.

(c) lo ³H = Low-level tritium analysis (10-pCi/L detection limit), which includes an electrolytic preconcentration.

(d) U = Isotopic uranium-234, uranium-235, and uranium-238.

(e) Collected hourly and composited for quarterly analysis.

(f) M Cont = River water was sampled for 2 weeks by continuous flow through a filter and resin column and multiple samples were composited monthly for analysis.

(g) Q Cont = River water was sampled for 2 weeks by continuous flow through a filter and resin column and multiple samples were composited quarterly for analysis.

(h) Pu = Isotopic plutonium-238 and plutonium-239/240.

(i) Numerous water quality analyses are performed by the U.S. Geological Survey under contract to Pacific Northwest National Laboratory.

(j) VOA = Volatile organic compounds.

Table 4.2.2. Columbia River Sediment Surveillance from Priest Rapids Dam to McNary Dam, 2003

<u>Location</u> ^(a)	<u>Frequency</u>	<u>Analyses</u>					
River		All river sediment analyses included gamma energy analysis, ⁹⁰ Sr, U ^(b) , Pu ^(c) , metals, SEM/AVS ^(d)					
Priest Rapids Dam: 2 locations near the dam	Annually						
White Bluffs Slough	Annually						
100-F Slough	Annually						
Hanford Slough	Annually						
Richland	Annually						
McNary Dam: 2 locations near the dam	Annually						
Springs		All springs sediment analyses included gamma energy analysis, ⁹⁰ Sr, U, metals					
100-B Area	Annually						
100-K Area	Annually						
100-N Area	Annually						
100-F Area	Annually </tr <tr> <td>Hanford town site springs</td> <td>Annually</td> <td></td> </tr> <tr> <td>300 Area</td> <td>Annually</td> <td></td> </tr>	Hanford town site springs	Annually		300 Area	Annually	
Hanford town site springs	Annually						
300 Area	Annually						

(a) See Figure 4.2.1.

(b) U = Isotopic uranium-234, uranium-235, and uranium-238 analyzed by low-energy photon analysis.

(c) Pu = Isotopic plutonium-238 and plutonium-239/240.

(d) SEM/AVS = Simultaneously extracted metals and acid volatile sulfide.

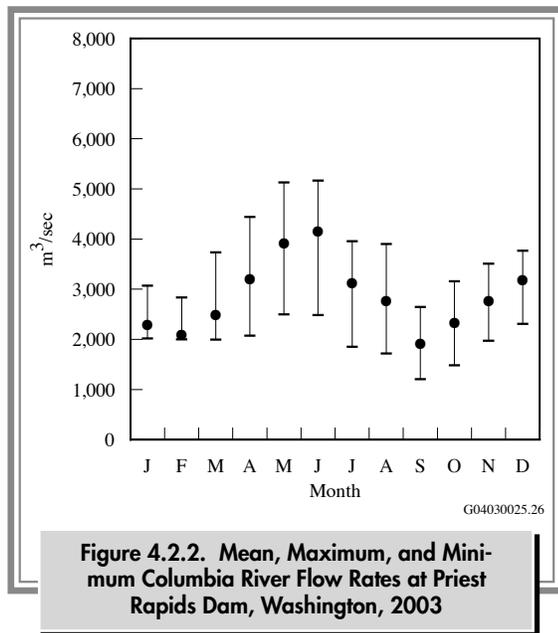


Figure 4.2.2. Mean, Maximum, and Minimum Columbia River Flow Rates at Priest Rapids Dam, Washington, 2003

magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from approximately 300 to 1,000 meters (980 to 3,300 feet) through the Hanford Site.

Hanford pollutants, both radiological and chemical, enter the Columbia River along the Hanford Reach. Effluent from each direct discharge point is monitored routinely and reported by the responsible operating contractor (Section 3.1). Direct discharges are identified and regulated for non-radiological constituents under the National Pollutant Discharge Elimination System in compliance with the *Clean Water Act* (Section 2.2.8). In addition to permitted direct discharges of liquid effluent from Hanford facilities, contaminants in groundwater from past operational discharges to the ground seep into the river (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006).

Washington State has classified the general water use and water quality criteria for the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (WAC 173-201A). Water quality criteria and water use guidelines have been established in conjunction with this designation and are provided in Appendix D (Table D.1).

4.2.1.1 Collection of River-Water Samples and Analytes of Interest

During 2003, samples were collected from fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, and from Columbia River transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland (Figure 4.2.1). Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and the Vernita Bridge to provide background data from locations unaffected by site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford Site operations, including a municipal drinking water supply and points of withdrawal for irrigation water downstream of the Hanford Site. Sampling of irrigation water systems is discussed in Section 4.2.5.

The fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, consisted of both an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were obtained hourly to collect a composite sample for a period of 7 days. These weekly samples were combined into monthly and quarterly composite samples for radiological analyses (Table 4.2.1). Using the continuous flow system, particulate and soluble constituents in Columbia River water were collected by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into quarterly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in detail in DOE/RL-91-50.

Radionuclides of interest were selected for analysis based on the following criteria:

- Their presence in effluent discharged from site facilities or in near-river groundwater underlying the Hanford Site.
- Their importance in determining water quality, verifying effluent control and monitoring systems, and determining compliance with applicable standards.

Analytes of interest in river water samples collected at Priest Rapids Dam and Richland, Washington, included gross alpha, gross beta, selected gamma-emitting radionuclides, tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium 238, and plutonium-239/240. Gross alpha and beta measurements are indicators of the general radiological quality of the river and provide a timely indication of change. Gamma energy analysis provides the ability to detect numerous specific radionuclides (Appendix F). Analytical detection levels (defined as the laboratory reported minimum detectable concentration) for all radionuclides were less than or equal to 10% of their respective water quality criteria levels (Appendix D, Tables D.1 and D.2). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, alpha at 5% significance level.

Transect sampling (multiple samples collected along a line across the Columbia River) was initiated as a result of findings of a special study conducted during 1987 and 1988 (PNL-8531). That study concluded that, under certain flow conditions, contaminants entering the river from the Hanford Site are not completely mixed when sampled at routine monitoring stations located downriver. Incomplete mixing results in a slightly conservative (high) bias in the data generated using the routine, single-point, sampling system at Richland, Washington. During 1999, the transect sampling strategy was modified, with some of the mid-river sampling points shifted to near-shore locations in the vicinity of the transect. For example, at the 100-N Area instead of collecting ten evenly spaced cross-river transect samples, only six cross-river samples were collected, and the other four samples were obtained at near-shore locations (typically less than 5 meters [16 feet] from shore). This sampling pattern was used during 2003 and allowed the cross-river concentration profile to be determined and also provided information



over a larger portion of the Hanford shoreline where the highest contaminant concentrations would be expected. The Vernita Bridge and Richland, Washington, transects and near-shore locations were sampled quarterly during 2003. Annual transect and near-shore sampling were conducted at the 100-N Area, 100-F Area, Hanford town site, and 300 Area locations in late summer when river flows were low to provide the highest probability of detecting Hanford contaminants (PNL-8531).

Columbia River transect water samples collected during 2003 were analyzed for both radiological and chemical contaminants (Table 4.2.1). Metals and anions were selected for analysis following reviews of existing surface-water and groundwater data, various remedial investigation/feasibility study work plans, and preliminary Hanford Site risk assessments (DOE/RL-92-67; PNL-8073; PNL-8654; PNL-10400; PNL-10535). All radiological and chemical analyses of transect samples were performed on grab samples of unfiltered water, except for metals analyses, which were performed on both filtered and unfiltered samples.

In addition to monitoring conducted by Pacific Northwest National Laboratory, water quality monitoring was performed by the U.S. Geological Survey for the Pacific Northwest National Laboratory. Samples were collected three times per year along Columbia River transects at Vernita Bridge and Richland (Appendix C, Table C.6). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado, for numerous physical parameters and chemical constituents.

4.2.1.2 Radiological Results for River-Water Samples

Fixed Location Sampling. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and Richland, Washington, during 2003 are reported in PNNL-14687, APP. 1 and summarized in Appendix C (Tables C.1 and C.2). These tables also list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2003 and for the previous 5 years. All individual radiological contaminant concentrations measured in Columbia River water during 2003 were less than DOE derived concentration guides (DOE Order 5400.5), less than 1/25 of the DOE derived concentration guides (i.e., DOE derived concentration guides are based on a 100 mrem

(1 mSv) standard; dividing by 25 allows for more direct comparison of the 4 mrem (0.04 mSv) standard used for drinking water), and Washington State ambient surface-water quality criteria (WAC 173-201A and 40 CFR 141; Appendix D, Tables D.2, D.3, and D.5). Significant results are discussed in the following paragraphs, and comparisons to previous years are provided.

Radionuclide concentrations monitored in Columbia River water were low throughout the year. During 2003, the radionuclides tritium, strontium-90, iodine-129, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. The concentrations of all other radionuclides were typically below the minimum detectable concentrations. Tritium, strontium-90, iodine-129, and plutonium-239/240 exist in worldwide fallout from historical nuclear weapons testing, as well as in effluent from Hanford facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

The 2003 average gross alpha and gross beta concentrations measured upstream and downstream of the Hanford Site were similar to those observed during recent years. Statistical comparisons for gross alpha and gross beta concentrations at Priest Rapids Dam and Richland were not performed because the majority of the concentrations were below the 1 and 3 pCi/L (0.037 and 0.11 Bq/L) minimum detectable concentrations, respectively (Figures 4.2.3 and 4.2.4). The average gross alpha and gross beta concentrations in Columbia River water at Richland during 2003 were less than the Washington State ambient surface-water quality criteria levels of 15 and 50 pCi/L (0.56 and 1.9 Bq/L).

The 2003 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years. Statistical analyses indicated that monthly tritium concentrations in river water samples at Richland were higher than concentrations in samples from Priest Rapids Dam (Figure 4.2.5). However, 2003 average tritium concentrations in Columbia River water collected at Richland were only 0.4% of the Washington State ambient surface-water quality criteria level of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river include



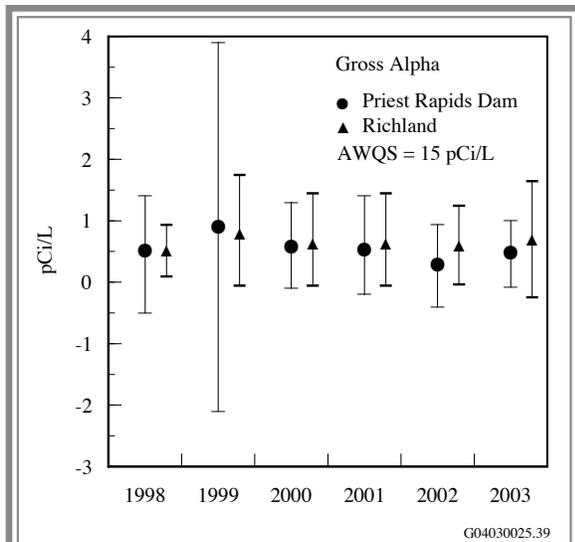


Figure 4.2.3. Annual Average Gross Alpha Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

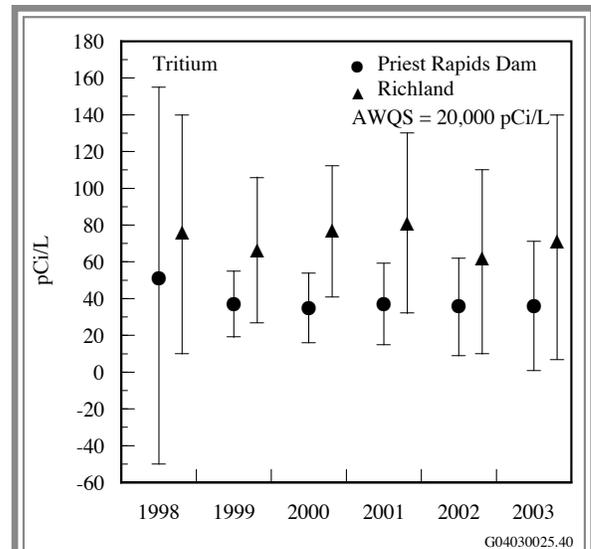


Figure 4.2.5. Annual Average Tritium Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

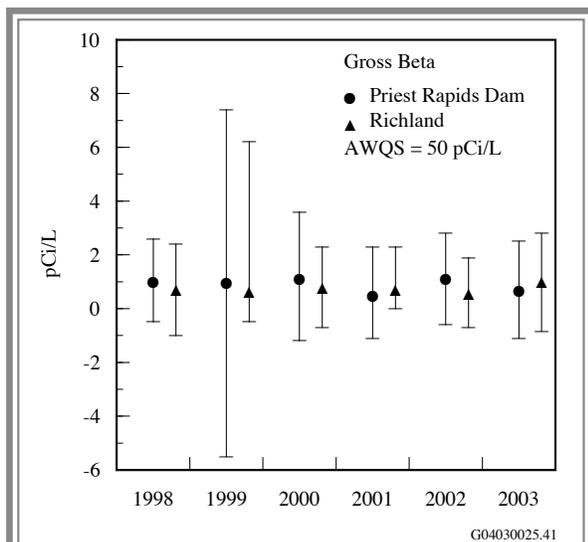
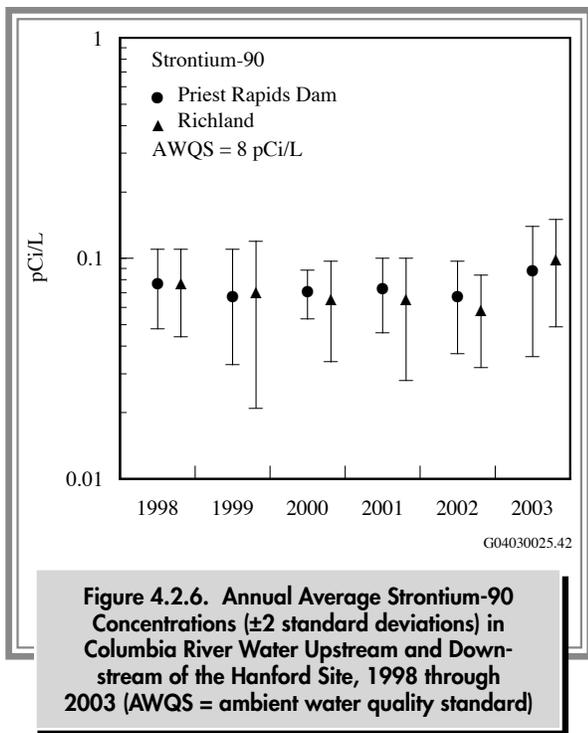


Figure 4.2.4. Annual Average Gross Beta Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

groundwater seepage and direct discharge from the 100-K Area permitted outfall (Section 3.1.3). Tritium concentrations measured at Richland, while representative of river water used by the city of Richland for drinking water, tend to overestimate the average tritium concentrations across the river at this location (PNL-8531). This

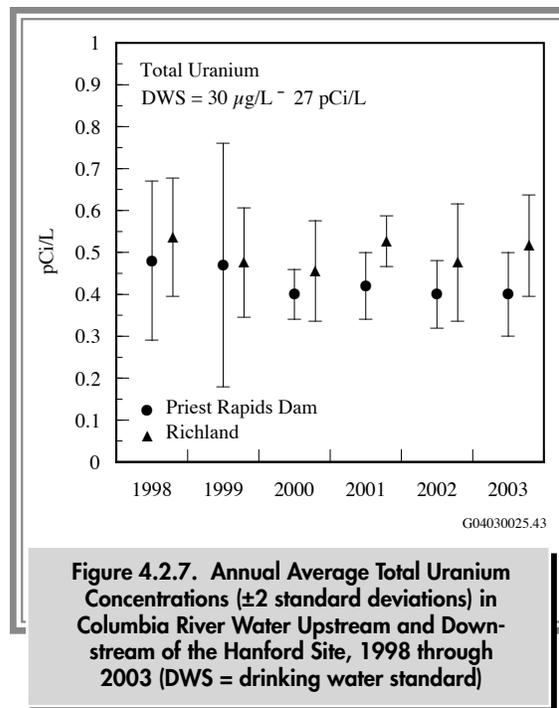
bias is attributable to the contaminated 200 Areas' groundwater plume entering the river along the portion of shoreline extending from the Hanford town site to below the 300 Area, which is relatively close to the Richland sample intake. This plume is not completely mixed within the river at Richland. Sampling along cross-river transects at Richland during 2003 confirmed the existence of a concentration gradient in the river under certain flow conditions and is discussed subsequently in this section. The extent to which samples taken at Richland overestimate the average tritium concentrations in the Columbia River at this location is variable and appears to be related to the flow rate of the river just before and during sample collection.

Strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2003 were similar to those reported previously (Figure 4.2.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas. Some of the highest strontium-90 levels that have been found in onsite groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Despite the Hanford Site source, there was no statistical difference between monthly strontium-90 concentrations at Priest Rapids Dam and Richland



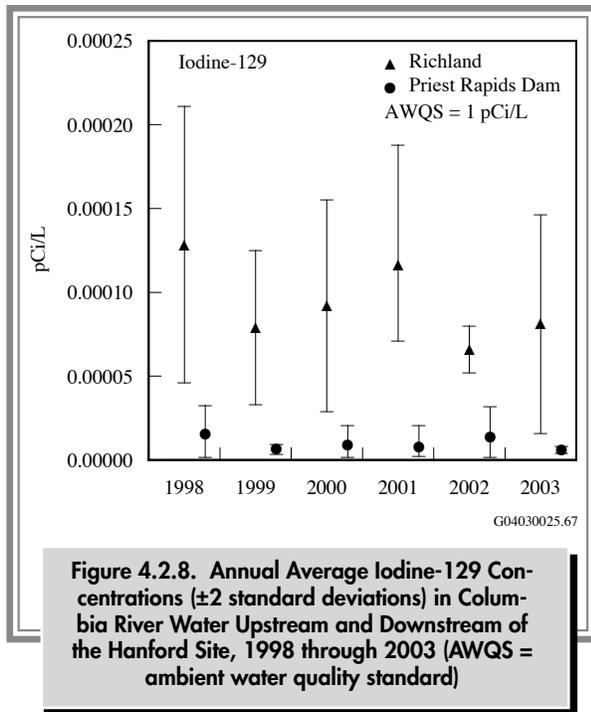
during 2003. Average strontium-90 concentrations in Columbia River water at Richland were less than 1.2% of the Washington State ambient surface-water quality criteria level (8 pCi/L [0.30 Bq/L]).

Annual average total uranium concentrations (i.e., the sum of uranium-234, uranium-235, uranium-238) observed in water samples collected upstream and downstream of the Hanford Site during 2003 were similar to those observed during recent years (Figure 4.2.7). Monthly total uranium concentrations measured at Richland during 2003 were statistically higher than those measured at Priest Rapids Dam. Although there is no direct process discharge of uranium to the river, uranium is present in the groundwater beneath the 300 Area as a result of past Hanford operations. Groundwater contaminants have been detected at elevated levels in riverbank springs at the 300 Area in the past (Section 4.2.3 and PNNL-13692). Uranium is also known to enter the river across from the Hanford Site via irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500). There are no Washington State ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium levels in the river during 2003 were well below the



EPA drinking water standard of 30 $\mu\text{g/L}$ (approximately 27 pCi/L [1.0 Bq/L], Appendix D, Table D.2).

The average iodine-129 concentration in Columbia River water measured downstream of the Hanford Site at Richland was extremely low during 2003 (0.008% of the Washington State ambient surface-water quality criteria level of 1 pCi/L [0.037 Bq/L]) and similar to levels observed during recent years (Figure 4.2.8). The onsite source of iodine-129 to the Columbia River is the discharge of contaminated groundwater along the portion of shoreline downstream of the Hanford town site. The iodine-129 plume originated in the 200 Areas from past waste disposal practices. Quarterly iodine-129 concentrations in Columbia River water at Richland were statistically higher than those at Priest Rapids Dam indicating a Hanford source of iodine-129. In general, the iodine-129 values at Priest Rapids Dam are largely unaffected by river stage; however, the concentrations measured for river water at Richland are inversely proportional to river stage (i.e., during lower flow, the concentrations of iodine-129 are higher and vice versa). The influence of river stage on concentrations of iodine-129 at Richland is reflected in the larger standard deviation, compared to the samples from Priest Rapids Dam, for the annual averages shown in Figure 4.2.8.



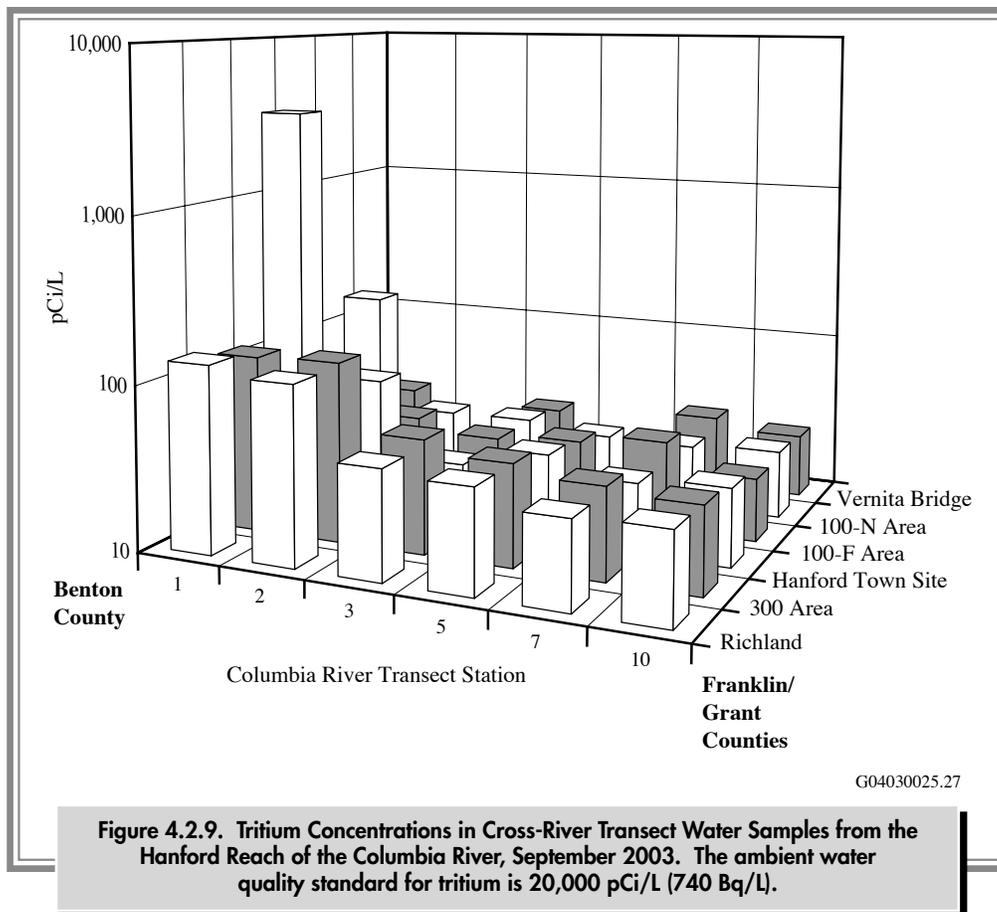
Average plutonium-239/240 concentrations for filtered river water samples at Richland were extremely low during 2003. Plutonium was only above the average minimum detectable concentration of 0.00004 pCi/L (0.000015 Bq/L) for the particulate fraction of the continuous water sample (i.e., detected on the filters but not detected on the resin column [dissolved fraction]). All concentrations were below the DOE derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.5). No Washington State ambient surface-water quality criteria level exists for plutonium-239/240. Results for filter samples for plutonium-239/240 were not statistically higher at Richland compared to Priest Rapids Dam; thus, there was no observed Hanford Site contribution. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and Richland were not performed because all of the concentrations were below the reported minimum detectable concentrations.

River Transect and Near-Shore Sampling. Radiological results from samples collected along Columbia River transects and at near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland during 2003 are presented in Appendix C (Tables C.3 and C.4) and PNNL-14687, APP. 1. Sampling locations were documented using a

global positioning system. Radionuclides consistently measured at concentrations greater than the minimum detectable activity included tritium, strontium-90, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable Washington State ambient surface-water quality criteria levels.

Tritium concentrations measured along Columbia River transects during September 2003 are depicted in Figure 4.2.9. The results are displayed such that the observer's view is upstream from Richland. The Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the Benton County and Franklin/Grant Counties shorelines, respectively. The 100-N Area, Hanford town site, 300 Area, and Richland transects have higher tritium concentrations near the Hanford (Benton County) shore relative to the opposite shore. The presence of a tritium concentration gradient in the Columbia River at Richland supports previous studies showing that contaminants in the 200 Areas' groundwater plume entering the river at, and upstream of, the 300 Area are not completely mixed at Richland (HW-73672; PNL-8531). The gradient is most pronounced during periods of relatively low river flow. Since transect sampling began during 1987, the average tritium concentration measured along the Richland transect has been less than that measured in monthly composited samples from the transect, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. For samples collected in 2003, the highest tritium concentration detected in cross-river transect water was $3,400 \pm 560$ pCi/L (130 ± 21 Bq/L) (Appendix C, Table C.3), which was detected along the shoreline of the Hanford town site. This is a location where groundwater containing tritium at concentrations greater than the Washington State ambient surface-water quality criterion (20,000 pCi/L [740 Bq/L]) is known to discharge to the river (Chapter 6, Figure 6.0.14).

Tritium concentrations for near-shore water samples collected at the Hanford (Benton County) shoreline (typically less than 5 meters [16 feet] from shore) during September 2003 are shown in Figure 4.2.10. The near-shore sampling locations are identified according to Hanford river markers, which are a series of signpost markers (approximately 1.6 kilometers [1 mile] apart) that originate at the Vernita Bridge (Hanford river marker #0) and end at Ferry Street in Richland (Hanford river marker #46).

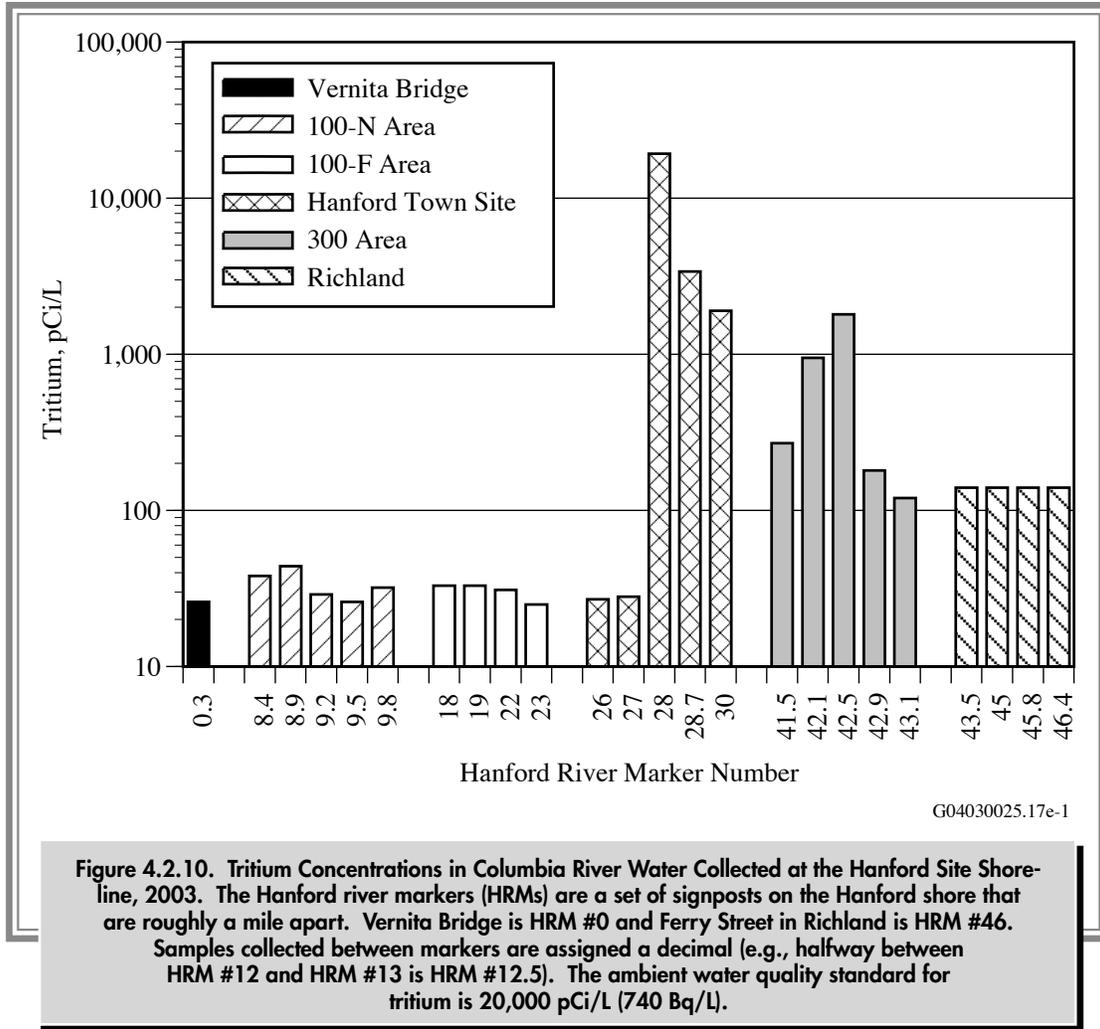


The concentrations of tritium in near-shore water samples collected at the 100-N Area, Hanford town site, 300 Area, and Richland were elevated compared to concentrations in samples collected near the Vernita Bridge. There was a wide range of tritium concentrations measured for the shoreline samples with the concentrations increasing near discharge points for the groundwater tritium plume (Chapter 6, Figure 6.0.14). During 2003, the highest tritium concentration observed in near-shore water samples was $19,000 \pm 1,400$ pCi/L (700 ± 52 Bq/L) (Appendix C, Table C.4), which was detected along the shoreline of the Hanford town site at Hanford river marker #28. This location is roughly 1 kilometer (0.6 mile) upriver from the cross-river transect sampling location where the maximum tritium level was $3,400 \pm 560$ pCi/L (130 ± 21 Bq/L).

During 2003, strontium-90 concentrations in Hanford Reach river water for both transect and near-shore samples were similar to background concentrations for all locations, except for the 100-N Area. The 100-N Area had

elevated strontium-90 concentrations in some samples obtained at near-shore locations. The average strontium-90 concentration found during transect sampling at Richland was similar to those measured in monthly composite samples from Richland, indicating that strontium-90 concentrations in water collected from the fixed-location monitoring station are representative of the average strontium-90 concentrations in the river at this location.

Total uranium concentrations in Hanford Reach water during 2003 were elevated along the Benton and Franklin County shorelines for the 300 Area transect. Total uranium concentrations were also elevated along the Franklin County shoreline for the Richland transect. The highest total uranium concentration was measured in March near the Franklin County shoreline of the Richland transect (1.2 ± 0.16 pCi/L [0.044 ± 0.0059 Bq/L]) (Appendix C, Table C.3) and likely resulted from groundwater seepage and water from irrigation return canals on the Franklin County side of the river that contained naturally occurring uranium (PNL-7500).



4.2.1.3 Chemical and Physical Results for River-Water Samples

Pacific Northwest National Laboratory and the U.S. Geological Survey (under contract to Pacific Northwest National Laboratory) compiled chemical and physical water quality data for the Columbia River during 2003. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and contaminants of Hanford origin. Potential sources of pollutants not associated with Hanford include irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500) and industrial, agricultural, and mining effluent located upstream from the Hanford Site.

River Transect and Near-Shore Samples. Results of chemical sampling conducted by Pacific Northwest

National Laboratory along transect and near-shore locations of the Columbia River at the Vernita Bridge, 100-F Area, 100-N Area, Hanford town site, 300 Area, and Richland are provided in PNNL-14687, APP. 1. The concentrations of metals and anions observed in river water during 2003 were similar to those observed in the past and remain below regulatory limits. Several metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Arsenic, antimony, cadmium, lead, nickel, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium, cadmium, chromium, lead, selenium, silver, and thallium were detected occasionally. For samples collected on the cross-river transects, concentrations of chloride, nitrate, and sulfate measured near the Hanford shoreline transect samples were elevated at the 300 Area and the Hanford town site. Nitrate concentrations for water samples from the Benton County

shoreline near Richland were slightly higher compared to mid-river samples. Chloride, nitrate, and sulfate concentrations were elevated, compared to mid-river samples, along the Franklin County shoreline at Richland and 300 Area transects and likely resulted from groundwater seepage associated with extensive irrigation (the water for which is drawn from the Columbia River upstream of the Hanford Site) north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by the U.S. Geological Survey (1995) and is associated with high fertilizer and water usage in agricultural areas. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141; USGS Circular 1144). Average chloride, nitrate, and sulfate results were slightly higher for quarterly concentrations at the Richland transect compared to the Vernita Bridge transect.

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.3). Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as calcium carbonate, the limiting value based on U.S. Geological Survey monitoring of Columbia River water near the Vernita Bridge and Richland over the past years. The total hardness reported by the U.S. Geological Survey at those locations from 1992 through 2003 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the Washington State ambient surface-water quality criteria levels for the protection of aquatic life (Appendix C, Table C.5 and Appendix D, Table D.3). Arsenic concentrations exceeded the EPA standard for the protection of human health for the consumption of water and organisms; however, this EPA value is approximately 10,500 times lower than the Washington State chronic toxicity value and similar concentrations were found at the Vernita Bridge and Richland (Appendix D, Table D.3). The concentrations of volatile organic compounds in Columbia River water samples (e.g., chlorinated solvents, benzene) were below detection limits in most samples, with no indication of a Hanford source.

U.S. Geological Survey. Figure 4.2.11 shows U.S. Geological Survey results for the Vernita Bridge and at Richland for 1998 through 2003 (2003 results are preliminary)

for water quality parameters with respect to their applicable standards. The list of preliminary results is documented in PNNL-14687, APP. 1 and is summarized in Appendix C (Table C.6). Final results are published annually by the U.S. Geological Survey (e.g., WA-99-1). The 2003 U.S. Geological Survey results were comparable to those reported during the previous 5 years. Applicable standards for a Class A-designated surface-water body were met. During 2003, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (Appendix D, Table D.1).

4.2.2 Riverbank Spring Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site. Groundwater provides a means for transporting Hanford-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006). Contaminated groundwater enters the Columbia River via surface and subsurface discharge. Discharge zones located above the water level of the river are identified in this report as riverbank springs. Routine monitoring of riverbank springs offers the opportunity to characterize the quality of groundwater being discharged to the river and to assess the potential human and ecological risk associated with the spring water. In addition, contaminants in groundwater near the Columbia River are monitored using aquifer sampling tubes (Section 6.0.1.1) (PNNL-14444). The contaminant concentrations in water from riverbank springs are typically lower than those found in near-shore groundwater wells because of bank storage effects.

The seepage of groundwater into the Columbia River has occurred for many years. Riverbank springs were documented along the Hanford Reach long before Hanford Site operations began during World War II (Jenkins 1922). During the early 1980s, researchers walked a 66-kilometer (41-mile) stretch of the Benton County shoreline of the Hanford Reach and identified 115 springs (PNL-5289). They reported that the predominant areas of groundwater discharge at that time were in the vicinity of the 100-N Area, Hanford town site, and 300 Area. The predominance of the 100-N Area may no longer be valid because of



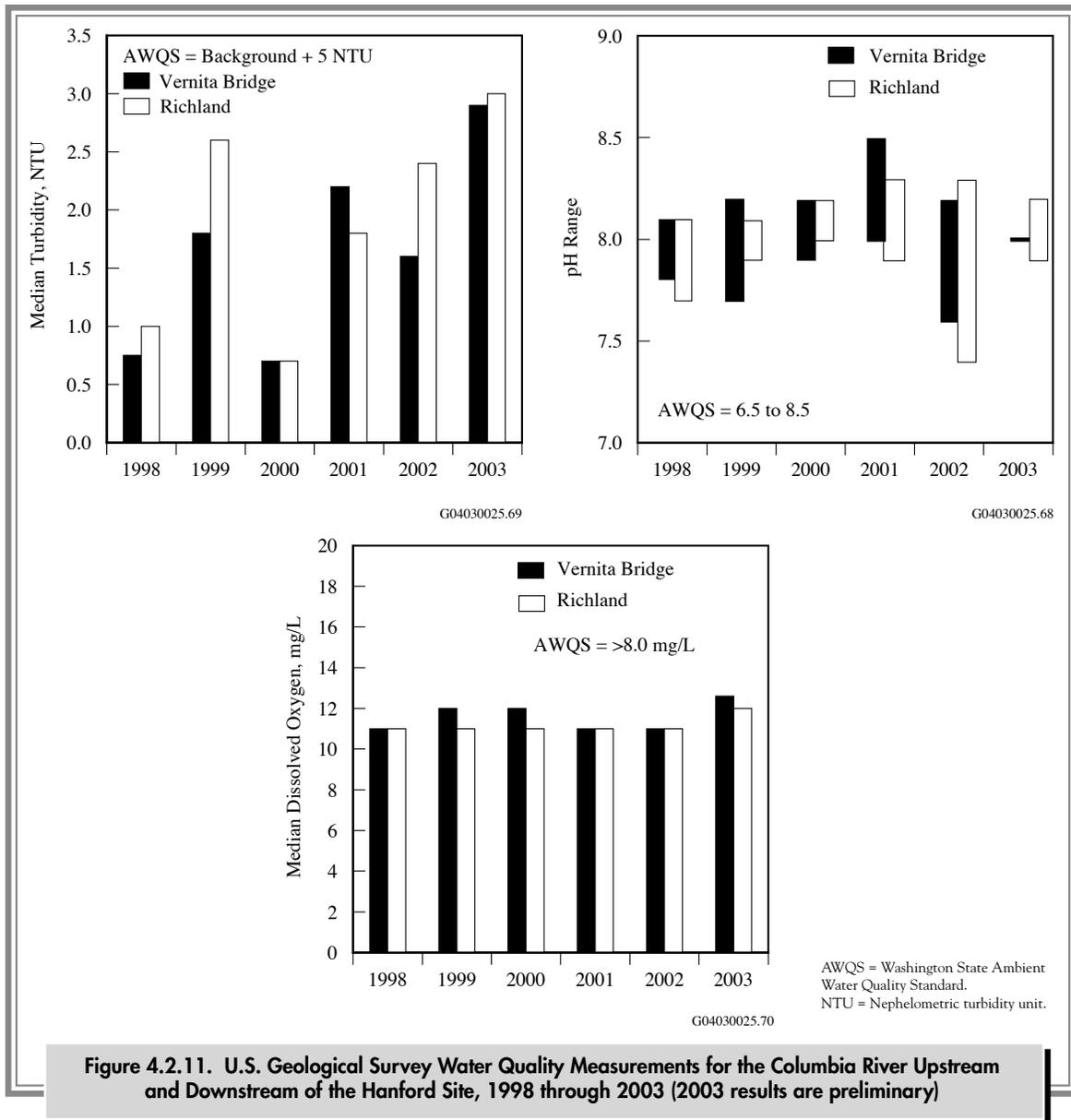


Figure 4.2.11. U.S. Geological Survey Water Quality Measurements for the Columbia River Upstream and Downstream of the Hanford Site, 1998 through 2003 (2003 results are preliminary)

declining water-table elevations in response to the cessation of liquid waste discharges to the ground from Hanford Site operations, and the pump-and-treat systems that are being used to decontaminate groundwater at the 100-N Area. In recent years, it has become increasingly difficult to locate riverbank springs in the 100-N Area.

The presence of riverbank springs also varies with river stage. Groundwater levels in the Hanford Reach are heavily influenced by river stage fluctuations. Water levels in the Hanford Reach of the Columbia River are controlled by upriver conditions and operations at Priest Rapids Dam. As water levels fluctuate, groundwater levels and, thus, the presence of riverbank springs in the Hanford Reach vary.

In addition, for the 300 Area, the water levels are influenced by the height of the McNary Dam pool. Water flows into the aquifer (as bank storage) as the river stage rises and then discharges from the aquifer in the form of a riverbank spring as the river stage falls. Following an extended period of low river flow, groundwater discharge zones located above the water level of the river may cease to exist once the level of the groundwater comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage. Bank storage of river water also affects the contaminant concentration of the springs. Spring water discharged immediately following a river stage decline generally consists of river

water or a mixture of river water and groundwater. The percentage of groundwater in the spring water discharge increases over time following a drop in river stage. Measuring the specific conductivity of the spring water discharge provides an indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductivity than Columbia River water.

Because of the effect of bank storage on groundwater discharge and contaminant concentration, as well as variations in aquifer thickness, porosity, and plume concentrations, it is difficult to accurately estimate the volume of contaminated groundwater discharged to the Columbia River within the Hanford Reach. Studies of riverbank springs conducted during 1983 (PNL-5289) and 1988 (PNL-7500), and results of near-shore studies (PNNL-11933; PNNL-13692) noted that discharges from the springs had only localized effects on river contaminant concentrations. These studies reported that the volume of groundwater entering the river at these locations was very small compared to the flow of the river and that the impact of groundwater discharges to the river flow was minimal.

4.2.2.1 Collection of Water Samples from Riverbank Springs and Analytes of Interest

Routine monitoring of selected riverbank springs was initiated during 1988. Currently, riverbank spring water samples are collected for environmental surveillance and to support groundwater operable unit investigations (Figure 4.2.1; DOE/RL-91-50). Analytes of interest for samples from riverbank springs were selected based on findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. Sampling is conducted annually when river flows are low, typically in early fall.

All samples collected during 2003 were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, iodine-129, and uranium-234, uranium-235, and uranium-238. All samples were analyzed for metals and anions, with volatile organic compounds analyzed at selected locations. All analyses were conducted on unfiltered samples, except for metals analyses, which

were conducted on both filtered and unfiltered samples (Appendix C, Table C.9; PNNL-14687, APP. 1).

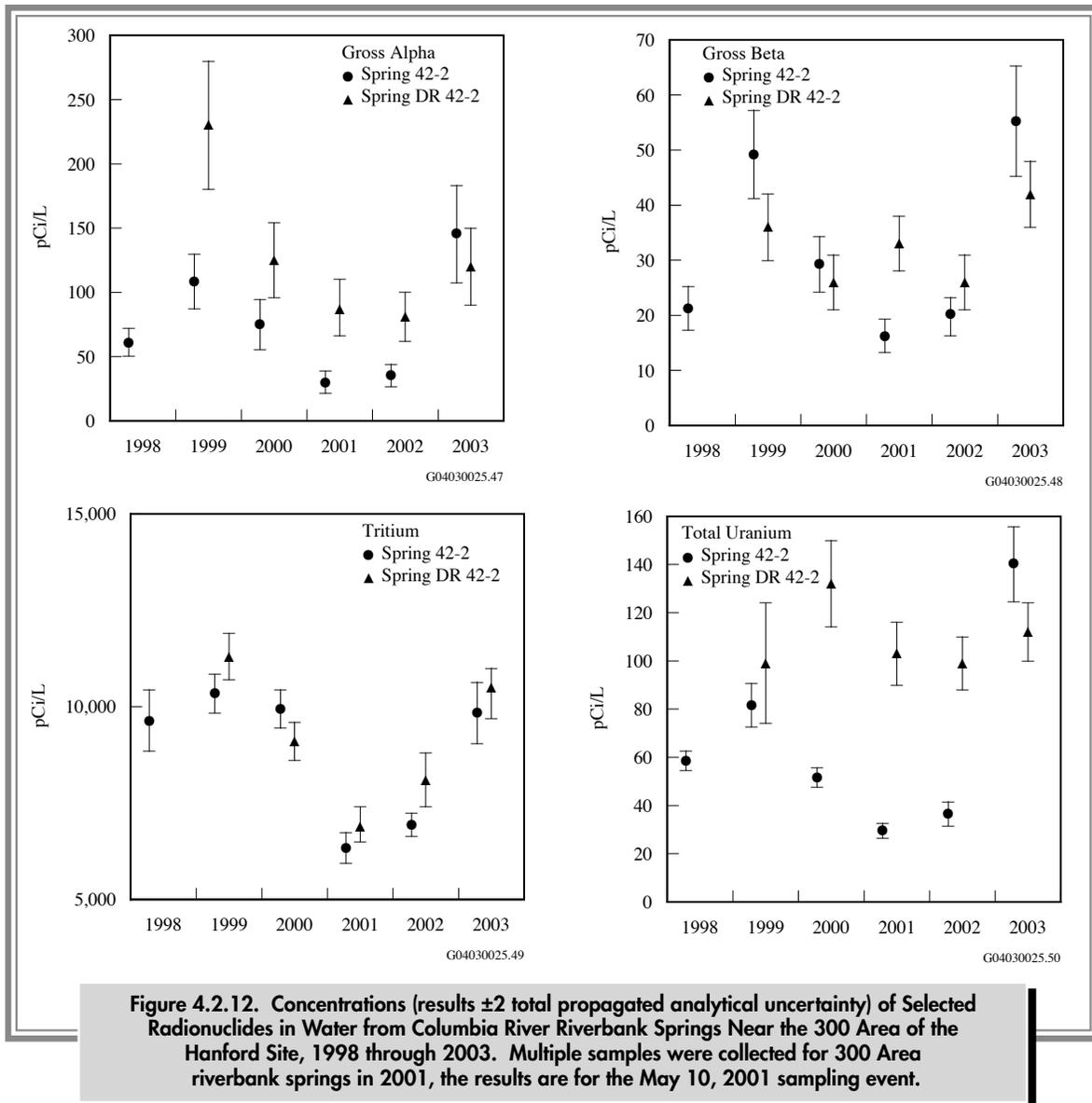
4.2.2.2 Radiological Results for Water Samples from Riverbank Springs

Contaminants of Hanford-origin continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2003. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238 were detected in spring water (Appendix C, Table C.9). All radiological contaminant concentrations measured in riverbank springs during 2003 were less than the DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5). However, the spring near well 199-N-8T at the 100-N Area that has historically exceeded the DOE derived concentration guide for strontium-90 only had observed flow during one (1997) sampling attempt in the last 7 years; thus, an alternative spring was sampled in the 100-N Area in 2003.

Gross beta concentrations in riverbank spring water at the 100-H Area, Hanford town site, and 300 Area were elevated compared to other riverbank spring water locations.

Tritium concentrations varied widely with location. The highest tritium concentration measured in riverbank springs was at the Hanford town site ($14,000 \pm 1,100$ pCi/L [520 ± 41 Bq/L]), which was below the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141), followed by the 300 Area ($10,000 \pm 820$ pCi/L [370 ± 30 Bq/L]), and the 100-N Area ($10,000 \pm 800$ pCi/L [370 ± 30 Bq/L]). Tritium concentrations in all riverbank spring samples were elevated compared to the 2003 average Columbia River concentration at Priest Rapids Dam (36 ± 35 pCi/L [1.3 ± 1.3 Bq/L]). Figure 4.2.12 depicts concentrations of selected radionuclides in the 300 Area riverbank spring water (spring 42-2 and spring DR 42-2) from 1998 through 2003. The elevated tritium levels measured in the 300 Area riverbank springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698). Tritium was the only specific radionuclide detected in 100-N Area riverbank spring water during 2003 (Table 4.2.3).





Samples from riverbank springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, 100-F, and 300 Areas. The highest strontium-90 concentration detected in riverbank spring water was at the 100-H Area (14 ± 2.0 pCi/L [0.52 ± 0.074 Bq/L]). This value exceeded the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L). Groundwater at the 100-N Area has the highest strontium-90 concentrations; however, from 1993 to 2003, there were no visible riverbank springs directly adjacent to wells 199-N-8T or 199-N-46, which are near the plume maximum. At the 100-N Area, the Surface Environmental Surveillance Project has not found a flowing riverbank spring at the intersection of the groundwater plume and the Columbia River since 1997.

Since 1997, riverbank spring samples at the 100-N Area have been collected from a downstream spring. Contaminant concentrations measured in water from the downstream spring were distinctly different from concentrations in the springs located near the shoreline wells (Table 4.2.3). Historically, the concentrations of strontium-90 and gross beta were considerably higher in the riverbank spring directly adjacent to well 199-N-8T than for the downstream spring.

Samples from riverbank springs in the 100-B, 100-K, 100-H Areas, and at the Hanford town site were analyzed for technetium-99. All results for technetium-99 were below the EPA drinking water standard of 900 pCi/L

Table 4.2.3. Selected Radionuclide Concentrations in 100-N Area Riverbank Spring Water at the Hanford Site, 1998 through 2003

Year	Concentration, pCi/L ^(a)		
	Tritium	Gross Beta	Strontium-90
1998 ^(b)	24,000 ± 1,900	2.3 ± 2.1	^(c)
1999 ^(b)	14,000 ± 670	2.9 ± 1.7	0.026 ± 0.034 ^(d)
2000 ^(b)	18,000 ± 800	5.9 ± 2.1	-0.0026 ± 0.037 ^(d)
2001 ^(b)	17,000 ± 800	3.7 ± 1.8	0.013 ± 0.043 ^(d)
2001 ^(b)	6,500 ± 430	5.5 ± 2.0	0.039 ± 0.044 ^(d)
2002 ^(b)	7,100 ± 320	4.8 ± 1.7	0.0042 ± 0.0034 ^(d)
2003 ^(b)	10,000 ± 800	9.3 ± 2.4	0.041 ± 0.063 ^(d)

- (a) Concentrations are ±2 total propagated analytical uncertainty. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.
- (b) Sample collected from riverbank spring downstream of well 199-N-8T (Spring 8-13).
- (c) Sample was lost during processing at the analytical laboratory.
- (d) Value below the detection limit.

(33 Bq/L) (Appendix D, Table D.2). The highest technetium-99 concentration was found in riverbank spring water from the Hanford town site (14 ± 1.1 pCi/L [0.52 ± 0.041 Bq/L]).

Samples from riverbank springs at the Hanford town site and 300 Area were analyzed for iodine-129. The highest concentration was measured in a water sample from the Hanford town site spring (0.14 ± 0.012 pCi/L [0.0052 ± 0.00044 Bq/L]). This Hanford town site value was roughly 30,000 times higher than the 2003 average measured at Priest Rapids Dam (0.0000046 ± 0.0000020 pCi/L [0.00000017 ± 0.000000074 Bq/L]) but was below the surface-water quality criteria level of 1 pCi/L (0.037 Bq/L) (Appendix D, Table D.2). Concentrations of selected radionuclides in riverbank spring water near the Hanford town site (spring 28-2) from 1998 through 2003 are provided in Figure 4.2.13. Annual fluctuations in these values may reflect the influence of bank storage during the sampling period.

Uranium was sampled in riverbank spring water in the 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2003 (Figure 4.2.12). The highest total uranium level was found in 300 Area spring water (140 ± 15 pCi/L [5.2 ± 0.56 Bq/L]) or approximately 160 ± 17 µg/L, which was collected from a spring located downgradient from

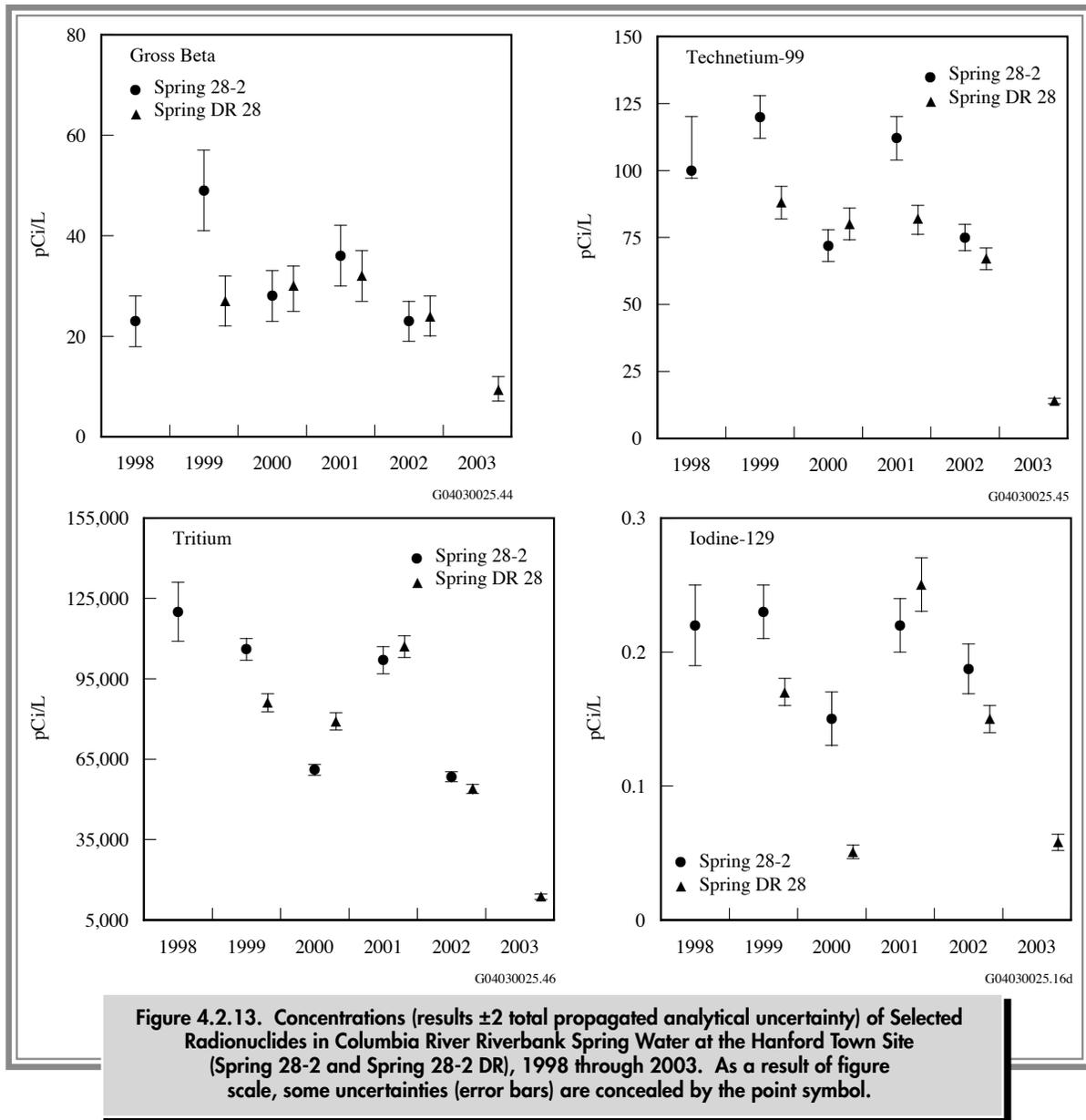
the retired 300 Area process trenches. The total uranium concentration in this spring exceeded the EPA drinking water standard of 30 µg/L (approximately 27 pCi/L [1.0 Bq/L]). The 300 Area spring had an elevated gross alpha concentration (140 ± 36 pCi/L [15 ± 1.3 Bq/L]). The gross alpha level in 300 Area spring water also exceeded the Washington State ambient surface-water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.2). Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of the former uranium fuel fabrication facilities and inactive waste sites. The increase in uranium concentrations in the most recent samples from riverbank spring 42-2 is not unexpected. A pulse of increased uranium concentrations in groundwater was created by waste site excavation activities during fall 2002 at a location just inland of this riverbank spring (PNNL-14548). The pulse has passed well 399-1-10A, located adjacent to the spring, and has now probably discharged to the river. The gross alpha and gross beta concentrations in 300 Area riverbank springs water from 1998 through 2003 parallel uranium and are likely associated with its presence.

4.2.2.3 Chemical Results for Water Samples from Riverbank Springs

Hanford-origin contaminants continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2003. Metals and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Volatile organic compounds were near or below the detection limits for most samples; trichloroethene was the only analyte with detectable values (2.2 µg/L at both 100-K Area spring 6-3 and 300 Area spring DR 42-2). Concentration ranges of selected chemicals measured in riverbank springs water during 1999 through 2003 are presented in Table 4.2.4. For most locations, the 2003 chemical sample results were similar to those reported previously (PNNL-12088). Nitrate concentrations were highest in the 300 Area. Chromium concentrations were generally highest in the 100-D, 100-K, and 100-H Areas' riverbank springs. Hanford groundwater monitoring results for 2003 indicated similar contaminant concentrations in shoreline areas (Chapter 6, Figure 6.0.6).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness





dependent (WAC 173-201A; Appendix D, Table D.3). For comparison purposes, spring water criteria were calculated using the same 47-mg calcium carbonate per liter hardness given in Appendix D, Table D.3. Most metal concentrations measured in water collected from riverbank springs along the Hanford Site shoreline during 1999 through 2003 were below Washington State ambient surface-water acute toxicity levels (WAC 173-201A). However, concentrations of chromium in 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas riverbank spring water were above Washington State ambient surface-water acute

toxicity levels (Appendix D, Table D.3). Arsenic concentrations in riverbank spring water were well below Washington State ambient surface-water chronic toxicity levels, but concentrations in all samples (including upriver Columbia River water samples) exceeded the federal limit for the protection of human health for the consumption of water and organisms; however, this EPA value is more than 10,500 times lower than the Washington State chronic toxicity standard (40 CFR 141; Appendix D, Table D.3). Nitrate concentrations at all spring water locations were below the drinking water standard (Appendix D, Table D.2).

Table 4.2.4. Concentration Ranges for Selected Chemicals in Water from Columbia River Springs at the Hanford Site, 1999 through 2003

	Ambient Water Quality Criterion Level ^(a)	Concentration, µg/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Town Site	300 Area
No. of Samples		12	10	6	8	14	6	8	7
Dissolved Metals (µg/L)									
Antimony	NA	0.081 - 0.31	0.13 - 0.24	0.16 - 0.24	0.17 - 0.22	0.18 - 0.42	0.096 - 0.23	0.13 - 0.39	0.18 - 0.36
Arsenic	190	0.93 - 1.6	0.32 - 2.1	1.4 - 3.4	0.60 - 1.3	0.30 - 3.0	1.5 - 2.6	2.5 - 4.8	0.95 - 2.9
Cadmium	0.59	0.0096 - 0.024	0.0044 - 0.051	0.011 - 0.031	0.017 - 0.093	0.0044 - 0.040	0.0091 - 0.023	0.010 - 0.089	0.012 - 0.078
Chromium	10 ^(b)	7.5 - 20	0.97 - 82	5.6 - 12	12 - 150	4.0 - 88	3.3 - 22	0.55 - 4.6	2.2 - 5.0
Copper	6	0.20 - 2.1	0.37 - 1.1	0.25 - 0.43	0.38 - 1.4	0.29 - 5.6	0.32 - 1.1	0.20 - 0.88	0.32 - 0.60
Lead	1.1	0.004 - 0.22	0.004 - 0.016	0.0050 - 0.016	0.0073 - 0.033	0.0050 - 0.57	0.0078 - 0.033	0.004 - 0.075	0.0050 - 0.062
Nickel	83	0.028 - 1.6	0.12 - 1.7	0.027 - 1.0	0.22 - 3.0	0.070 - 1.2	0.070 - 2.2	0.62 - 1.7	0.055 - 2.1
Silver	0.94 ^(c)	0.0012 - 0.021	0.0012 - 0.021	0.0012 - 0.021	0.0043 - 0.021	0.0050 - 0.021	0.0012 - 0.042	0.004 - 0.053	0.0049 - 0.021
Thallium	NA	0.0035 - 0.020	0.0035 - 0.023	0.0071 - 0.016	0.009 - 0.098	0.0059 - 0.026	0.0035 - 0.011	0.01 - 0.028	0.013 - 0.038
Zinc	55	0.14 - 5.0	0.43 - 3.7	1.2 - 3.7	1.2 - 12	0.35 - 5.0	0.66 - 2.5	0.54 - 3.1	0.93 - 3.0
No. of Samples		9	10	6	8	13	6	12	9
Total Recoverable Metals (µg/L)									
Chromium	96 ^(d)	7.2 - 20	1.2 - 93	7.6 - 14	11 - 190	4.0 - 99	10 - 33	0.88 - 5.4	1.9 - 24
Mercury	0.012	0.00042 - 0.0013 ^(c)	0.00098 - 0.014 ^(f)	0.00044 - 0.0062 ^(g)	0.00077 - 0.020 ^(c)	0.00056 - 0.041 ^(h)	0.0017 - 0.0076 ^(g)	0.00079 - 0.0028 ⁽ⁱ⁾	0.00074 - 0.0047 ^(c)
Selenium	5	0.50 - 2.2	0.11 - 2.2	0.41 - 0.96	0.50 - 2.7	0.39 - 2.9	0.68 - 2.3	0.45 - 2.3	1.7 - 4.1
No. of Samples		14	11	5	14 ^(j)	17	7	10	7
Anions (mg/L)									
Nitrate	45 ^(k)	0.1 - 3.4	0.028 - 4.9	2.0 - 4.9	0.41 - 6.3	0.10 - 20	0.58 - 33	1.1 - 8.1	3.2 - 6.4

(a) Ambient Water Quality Criteria Values (WAC 173-201A-040) for chronic toxicity unless otherwise noted.

(b) Value for hexavalent chromium.

(c) Value for acute toxicity; chronic value not available.

(d) Value for trivalent chromium.

(e) Number of samples = 7.

(f) Number of samples = 6.

(g) Number of samples = 4.

(h) Number of samples = 9.

(i) Number of samples = 10.

(j) One nitrate result of 295 mg/L for ri

(k) Drinking water standard (WAC 246-290).

NA = Not available.

4.2.3 Columbia River and Riverbank Springs Sediment

Upon release to the Columbia River, some radioactive and non-radioactive materials were deposited on the riverbed as sediment (particularly in upstream areas near dams). The concentrations of the radioactive material decreased as they underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of hydroelectric dams, annual spring high river flows, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the sediment (DOE/RL-91-50). Upper layer sediment in the Columbia River contains low concentrations of radionuclides and metals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout (Beasley et al. 1981; BNWL-2305; PNL-8148; PNL-10535). Potential public exposure is well below the level at which routine surveillance of Columbia River sediment is required (PNL-3127; Wells 1994). However, periodic sampling is necessary to confirm the low concentrations and to assure that no significant changes have occurred for this pathway. The accumulation of radioactive materials in sediment can lead to human exposure by ingestion of aquatic organisms associated with the sediment, sediment resuspension into drinking water supplies, or as an external radiation source irradiating people who are fishing, wading, sunbathing, or participating in other recreational activities associated with the river or shoreline (DOE/EH-0173T).

Since the shutdown of the last single-pass reactor at Hanford during 1971, the contaminant concentrations in the surface sediment have been decreasing as a result of radioactive decay and the subsequent deposition of uncontaminated material (Cushing et al. 1981). However, discharges of some pollutants from the Hanford Site to the Columbia River still occur via permit-regulated liquid effluent discharges at the 100-K Area (Section 3.1) and via contaminated groundwater seepage (Section 4.2.2).

Several studies have been conducted on the Columbia River to investigate the difference in sediment grain-size composition and total organic carbon content at routine monitoring sites (Beasley et al. 1981; PNL-10535; PNNL-13417). Physical and chemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Samples containing the highest

percentage of silts, clays, and total organic carbon were generally collected from the upstream pools at the dams and from White Bluffs Slough.

4.2.3.1 Collection of Sediment Samples and Analytes of Interest

During 2003, samples of the surface layer of Columbia River sediment were collected at depths of 0 to 15 centimeters (0 to 6 inches) from six river locations that were permanently (some Hanford Reach sampling locations may not be submerged during extremely low river stage) submerged and six riverbank springs that were periodically inundated (Figure 4.2.1 and Table 4.2.2). Sediment sampling locations were documented using a global positioning system.

Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam pool (the nearest upstream impoundment) to provide background data from an area unaffected by site operations. Samples were collected downstream of the Hanford Site above McNary Dam (the nearest downstream impoundment) to identify any increase in contaminant concentrations. Any increases in contaminant concentrations found in sediment above McNary Dam compared to that found above Priest Rapids Dam do not necessarily reflect a Hanford Site source. The confluences of the Columbia River with the Yakima, Snake, and Walla Walla Rivers lie between the Hanford Site and McNary Dam. Several towns, irrigation water returns, and factories in these drainages as well as atmospheric fallout from weapons testing also may contribute to the contaminant load found in McNary Dam sediment; thus, sediment samples are periodically taken at Ice Harbor Dam (the first dam on the Snake River upstream of the river mouth) to assess Snake River inputs (the most recent samples were collected during 2001). Sediment samples also were collected along the Hanford Reach of the Columbia River from areas close to contaminant discharges (e.g., riverbank springs), from slackwater areas where fine-grained material is known to deposit (e.g., the White Bluffs, 100-F Area, and Hanford Sloughs), and from the publicly accessible Richland shoreline that lies within the influence of the McNary Dam impoundment.

Monitoring sites at McNary and Priest Rapids Dams consisted of two stations spaced equidistant (approximately) on a transect line crossing the Columbia River; the samples



were collected near the boat exclusion buoys at each dam. All other monitoring sites consisted of a single sampling location. Samples of permanently inundated river sediment were collected using a clam-shell style sediment dredge. Samples of periodically inundated (covered by water) river sediment (riverbank springs sediment) were collected using a large plastic spoon, immediately following the collection of riverbank springs water samples. Sampling methods are discussed in detail in DOE/RL-91-50. All sediment samples were analyzed for gamma-emitting radionuclides (Appendix F), strontium-90, uranium-234, uranium-235, uranium-238, and metals (DOE/RL-91-50). Selected river sediment samples were also analyzed for plutonium-238 and plutonium-239/240. The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past and present effluent discharged from site facilities, and reviews of contaminant concentrations observed in groundwater monitoring wells near the river.

4.2.3.2 Radiological Results for Sediment Samples from Columbia River

Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2003 included potassium-40, strontium-90, cesium-137, uranium-238, plutonium-238, and plutonium-239/240. The concentrations of all other radionuclides were below the reported minimum detectable concentrations for most samples (PNNL-14687, APP. 1). Cesium-137 and plutonium isotopes exist in worldwide fallout, as well as in effluent from Hanford Site facilities. Potassium-40 and uranium occur naturally in the environment, and uranium is also present in Hanford Site effluent. No federal or state freshwater sediment criteria are available to assess the sediment quality of the Columbia River (EPA 822-R-96-001). Radionuclide concentrations reported in river sediment during 2003 were, with the exception of strontium-90, similar to those reported for previous years (Appendix C, Table C.7) and there were no obvious differences between locations. Strontium-90 concentrations were below the reported minimum detectable concentrations for most samples for years 2000 to 2002, but most 2003 results were detectable with values roughly eight to nine times higher than the previous

values. There were no obvious differences in concentrations for strontium-90 between upriver and downriver locations. The 2003 sediment samples submitted for strontium-90 analysis are currently being reanalyzed and the results are pending. Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (1998 through 2003) are presented in Figure 4.2.14.

4.2.3.3 Radiological Results for Sediment Samples from Riverbank Springs

Sampling of sediment from riverbank springs began during 1993 at the Hanford town site and the 300 Area. Sampling of the riverbank springs in the 100-B, 100-K, and 100-F Areas began during 1995. Substrates at riverbank springs sampling locations in the 100-N, 100-D, and 100-H Areas consist predominantly of large cobble and are unsuitable for sample collection.

During 2003, sediment samples were collected at riverbank springs in the 100-B, 100-F, and 300 Areas. No sediment was available for sampling at the 100-K Area location because the scheduled spring was not flowing and an alternate spring was sampled (i.e., only water samples were collected; no sediment was found). Results for 2003 samples (Figure 4.2.14) were similar to those observed for previous years (PNNL-14687; APP. 1; Appendix C, Table C.7). Potassium 40, cesium-137, and uranium isotopes were the only radionuclides reported above the minimum detectable concentrations. During 2003, radionuclide concentrations in riverbank spring sediment were similar to those observed in Columbia River sediment, with the exception of the 300 Area where uranium concentrations were roughly twice the background concentrations measured for sediment from Priest Rapids Dam. Elevated uranium concentrations for 300 Area spring sediment compared to Priest Rapids Dam sediment have been previously reported (PNNL-13692).

4.2.3.4 Chemical Results for Sediment Samples from the Columbia River and Riverbank Springs

Detectable amounts of most metals were found in all river sediment samples (Figure 4.2.15; Appendix C,



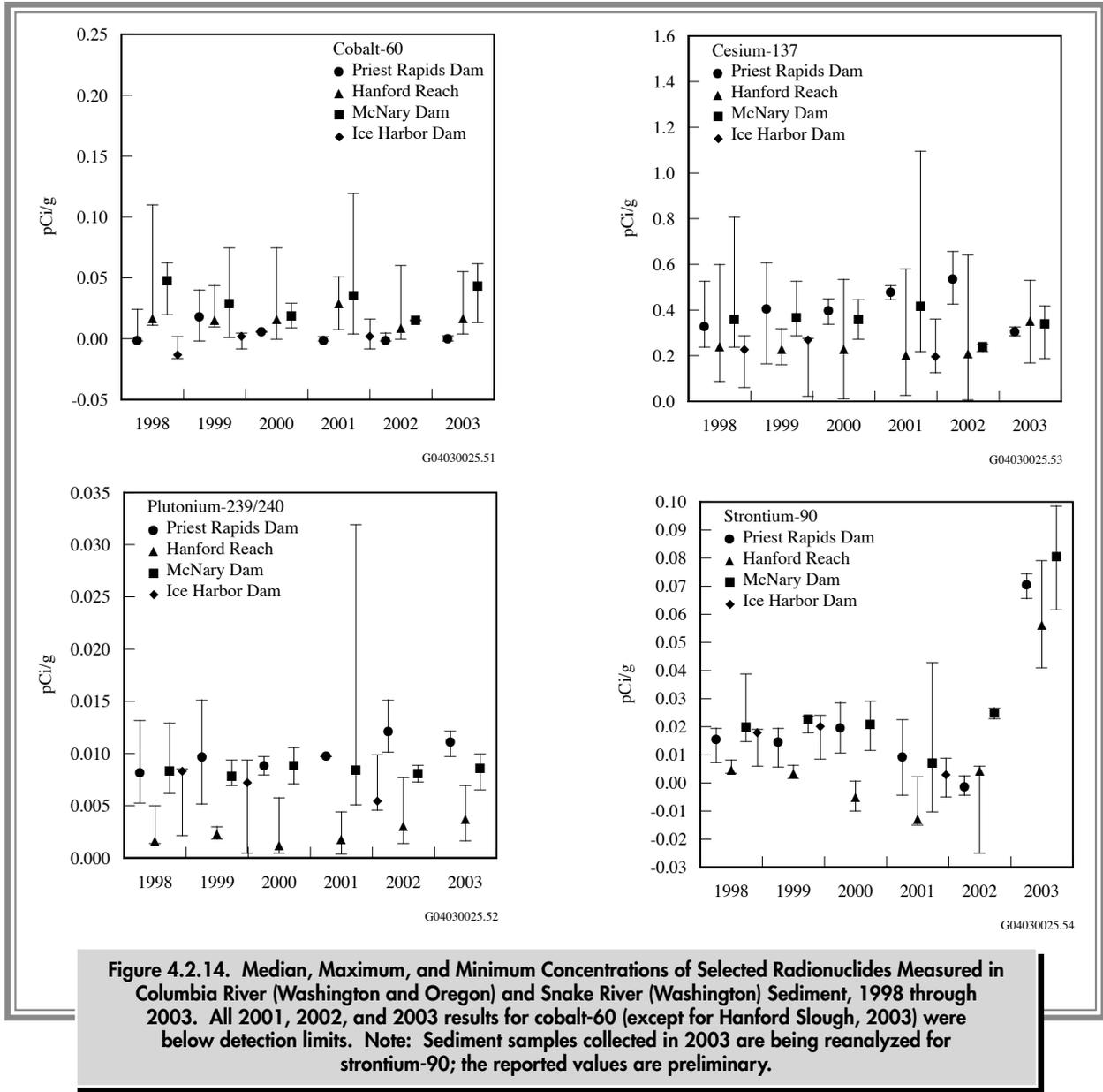


Table C.8; PNNL-14687, APP. 1). Maximum and median concentrations of most metals were higher for sediment collected at Priest Rapids Dam compared to either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, mercury, silver, and zinc had the largest differences between locations. Metal concentrations in riverbank spring sediment samples during 2003 were similar to concentrations in Hanford Reach Columbia River sediment samples. Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

Since 1997 (no samples were collected in 2001), annual Columbia River sediment samples have been analyzed for simultaneously extracted metals/acid volatile sulfide (SEM/AVS). This analysis involves a cold acid extraction of the sediment followed by analysis for sulfide and metals. The SEM/AVS ratios are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996; PNNL-13417). Acid volatile sulfide is an important binding phase for divalent metals (i.e., metals with a valence state of 2+, such as Pb²⁺) in sediment. Metal sulfide precipitates are typically very insoluble, and this limits the amount

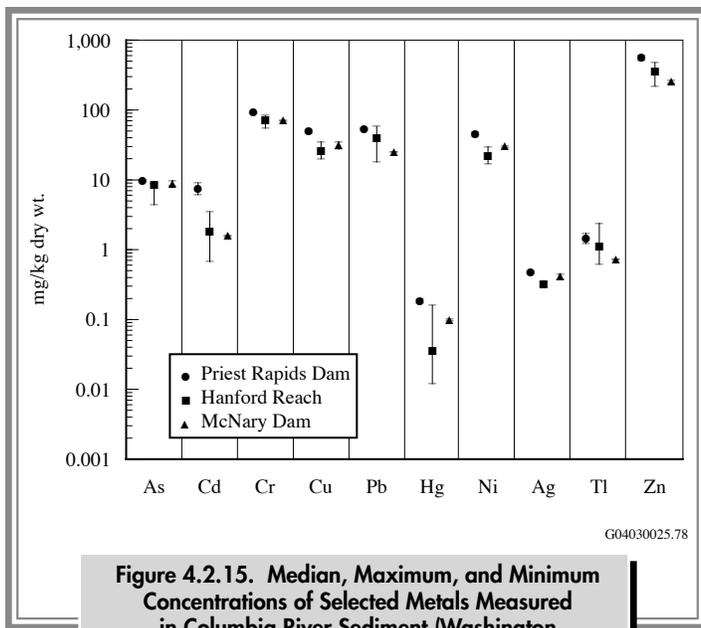


Figure 4.2.15. Median, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment (Washington and Oregon), 2003

of dissolved metal available in the sediment porewater. For an individual metal, when the amount of acid volatile sulfide exceeds the amount of the metal (i.e., the SEM/AVS molar ratio is below 1), the dissolved metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. For a suite of divalent metals, the sum of the simultaneously extracted metals must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the acid volatile sulfide.

The SEM/AVS results for the sediment collected during 2003 near Priest Rapids Dam and McNary Dam were similar to previous years (Figure 4.2.16). The average SEM/AVS results for the Hanford Reach sediment collected during 2003 were similar to previous years with concentrations varying from 0.41 to 14 $\mu\text{mol/g}$ (White Bluffs Slough had the highest measured acid volatile sulfide level). The sediment deposition locations in the Hanford Reach are more subject to annual variations in sediment parameters that can influence SEM/AVS results (e.g., sediment deposition rate, scouring by floods, changes in total organic carbon concentrations, and potential exposure to air during dry periods) than the sediment deposition areas upstream of the dams. During 2003, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging

from 3.8 to 7.5 $\mu\text{mol/g}$. Sediment from the McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.12 to 1.6 $\mu\text{mol/g}$. SEM/AVS molar ratios for sediment from the Priest Rapids Dam and McNary Dam reservoirs were above 1.0, indicating a potential for some dissolved metals to be present in the sediment porewater. Hanford Reach sediment samples had SEM/AVS molar ratios below one (i.e., low potential for dissolved metals in sediment porewater). For all locations, zinc was the primary SEM metal present.

Overall results from 1997 to 2003 reveal an apparent difference in the acid volatile sulfide concentrations in sediment from Priest Rapids Dam reservoir, which generally has higher concentrations than Hanford Reach and McNary Dam. An apportionment of acid volatile sulfide by divalent metals according to

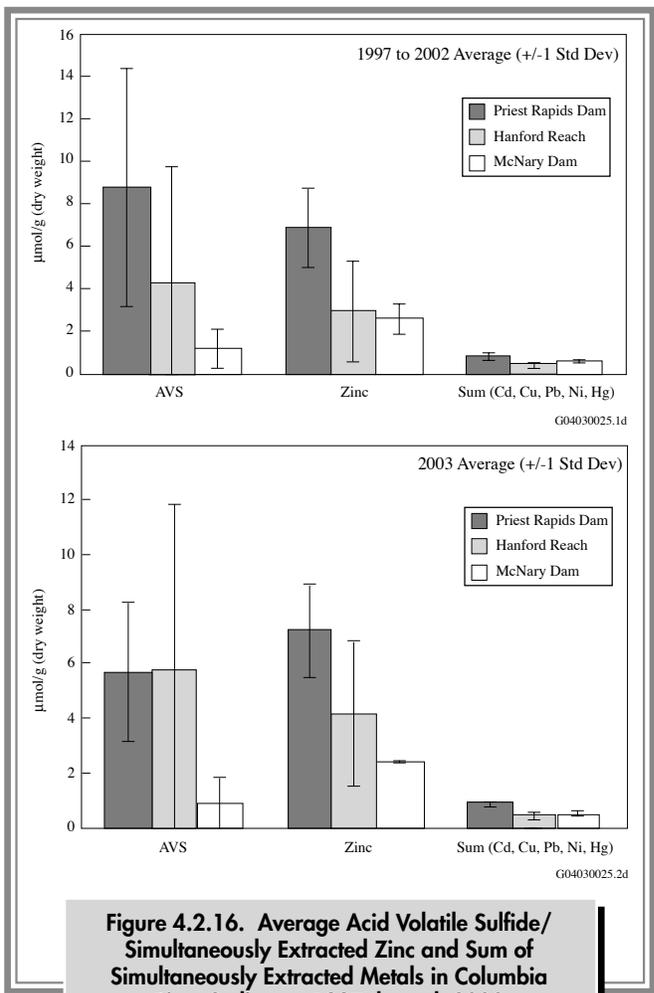


Figure 4.2.16. Average Acid Volatile Sulfide/Simultaneously Extracted Zinc and Sum of Simultaneously Extracted Metals in Columbia River Sediment, 1997 through 2000 Compared to 2003 Data

solubility values revealed that sufficient acid volatile sulfide should exist in all locations to limit the porewater concentrations of cadmium, copper, lead, and mercury. In Priest Rapids Dam and Hanford Reach sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. In McNary Dam sediment, the average zinc concentrations were higher than the available mean acid volatile sulfide pool, indicating the potential for zinc and possibly other dissolved metals to be present in the sediment porewater.

4.2.4 Onsite Pond Water and Sediment

Two onsite ponds (Figure 4.2.1), located near facilities in various stages of remediation, were sampled periodically during 2003. The ponds are inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2003. However, they were accessible to migratory waterfowl and deer, creating a potential biological pathway for the dispersion of contaminants (PNL-10174). The Fast Flux Test Facility pond is a disposal site for process water (primarily cooling water drawn from groundwater wells). West Lake, the only naturally occurring pond on the site, is located north of the 200-East Area (ARH-CD-775). West Lake has not received direct effluent discharges from Hanford Site facilities but is influenced by changing water-table elevation as a result of previous discharge of water to the ground in the 200 Areas.

4.2.4.1 Collection of Pond Water and Sediment Samples and Analytes of Interest

During 2003, grab samples were collected quarterly from the Fast Flux Test Facility pond (water) and from West Lake (water and sediment). All water samples were analyzed for tritium. Water samples from the Fast Flux Test Facility pond were also analyzed for gross alpha and gross beta concentrations, and gamma-emitting radionuclides. The groundwater table in the 200 East Area has decreased in recent years (Chapter 6) and this has decreased the size of West Lake and caused the suspended sediment loading to increase. Starting in 2002, it has not been practical for the analytical laboratory to process West Lake water samples for gross alpha, gross beta, strontium-90, technetium-99,

and uranium-234, uranium-235, and uranium-238 because of the high sediment load; thus, sediment samples were submitted for these analytes. Constituents were chosen for analysis based on their known presence in local groundwater, effluent discharged, and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

4.2.4.2 Radiological Results for Pond Water and Sediment Samples

All radionuclide concentrations in onsite pond water samples were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5) and Washington State ambient surface-water quality criteria levels (WAC 173-201A; 40 CFR 141; PNNL-14687, APP. 1; Appendix D, Tables D.1 and D.2).

Figure 4.2.17 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 1998 through 2003. Median levels of both constituents have remained stable in recent years. The median tritium concentration in Fast Flux Test Facility pond water during 2003 was 15% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L).

Median tritium concentrations in West Lake water during 2003 were similar to those observed in the past (Figure 4.2.18). The median concentration of tritium in West Lake water in 2003 was 0.8% of the Washington State ambient surface-water quality criterion level (20,000 pCi/L [740 Bq/L]) and reflected local groundwater concentrations.

Samples of West Lake sediment in 2003 had the following detectable values:

- Gross alpha – 5.5 to 17 pCi/g (0.20 to 0.63 Bq/g)
- Gross beta – 19 to 29 pCi/g (0.70 to 1.1 Bq/g)
- Potassium-40 – 14 to 17 pCi/g (0.52 to 0.63 Bq/g)
- Strontium-90 – 0.30 to 0.65 pCi/g (0.011 to 0.024 Bq/g)
- Cesium-137 – 0.80 to 1.8 pCi/g (0.030 to 0.067 Bq/g)
- Uranium-234 – 0.55 to 9.1 pCi/g (0.020 to 0.34 Bq/g)
- Uranium-235 – 0.022 to 0.34 pCi/g (0.00081 to 0.013 Bq/g)
- Uranium-238 – 0.50 to 8.5 pCi/g (0.018 to 0.32 Bq/g).



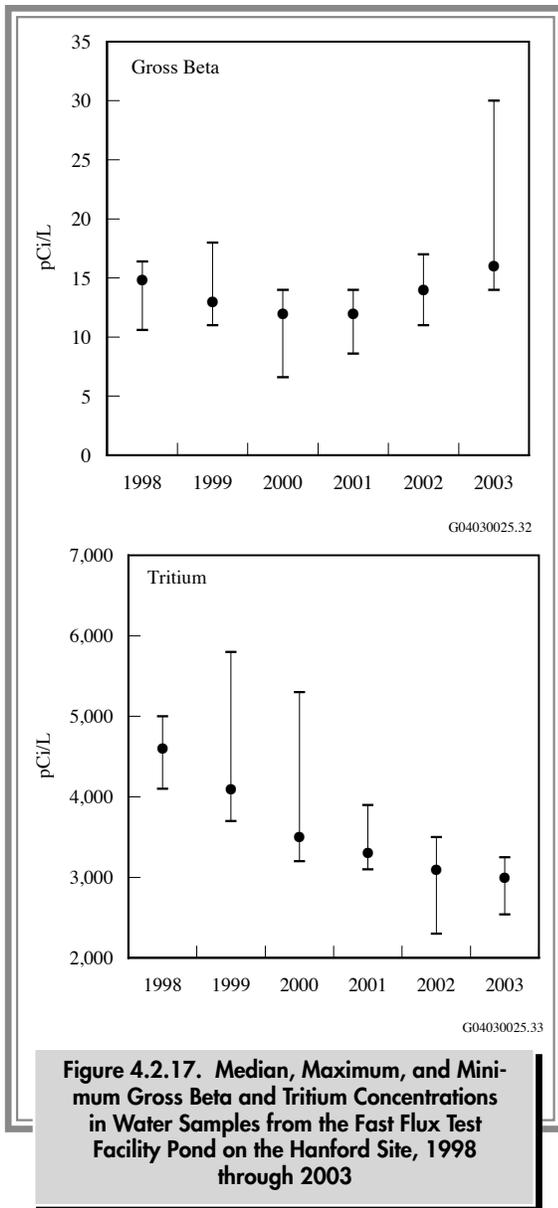


Figure 4.2.17. Median, Maximum, and Minimum Gross Beta and Tritium Concentrations in Water Samples from the Fast Flux Test Facility Pond on the Hanford Site, 1998 through 2003

These levels of radionuclides are similar to previous measurements (PNL-7662). Uranium concentrations are believed to result from high levels of naturally occurring uranium in the surrounding soil (BNWL-1979).

4.2.5 Irrigation Water

During 2003, water samples were collected from an irrigation canal located across the Columbia River and downstream from the Hanford Site at Riverview, and from an irrigation water supply on the Benton County shoreline near the southern boundary of the Hanford Site (Horn Rapids irrigation pumping station) (Figure 4.2.1). As a

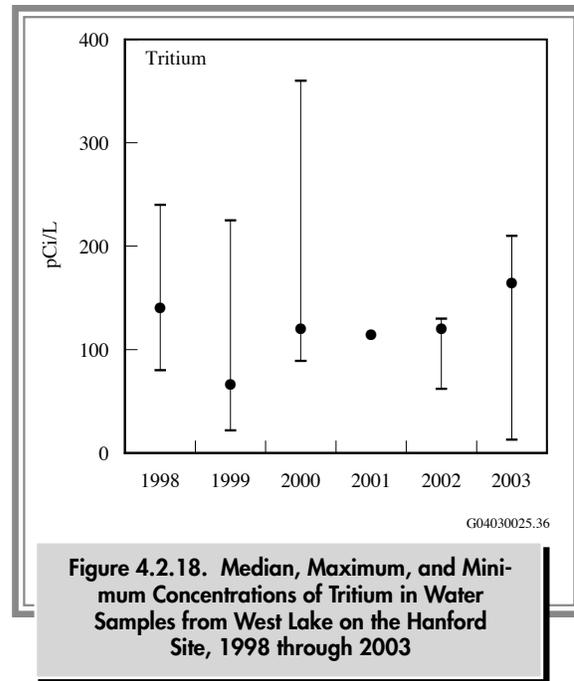


Figure 4.2.18. Median, Maximum, and Minimum Concentrations of Tritium in Water Samples from West Lake on the Hanford Site, 1998 through 2003

result of public concerns about the potential for Hanford-associated contaminants in offsite water, sampling was conducted to document the levels of radionuclides in water used by the public. Consumption of vegetation irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (Chapter 5).

Collection, Analysis, and Results for Irrigation Water

Water from the Riverview irrigation canal and the Horn Rapids irrigation pumping station was sampled three times during the 2003 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, tritium, strontium-90, and uranium-234, uranium 235, and uranium-238. During 2003, radionuclide concentrations measured in irrigation water were at the same levels detected in the Columbia River (PNNL-14687, APP. 1). All radionuclide concentrations were below their respective DOE derived concentration guides and Washington State ambient surface-water quality criteria levels (DOE Order 5400.5; WAC 173-201A; 40 CFR 141). Strontium-90 levels in all irrigation water samples during 2003 ranged from 0.082 ± 0.038 to 0.10 ± 0.036 pCi/L (0.0030 ± 0.0014 to 0.0037 ± 0.0013 Bq/L).